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MODERN TOOLS FOR ANALYZING THE RELATIONSHIP BETWEEN CAPITAL MARKET SENTIMENTS AND INVESTOR BEHAVIOR

SUMMARY

Scientific supervisor

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To my mother

Appreciation and thanks

The finalization of this work would not have been possible without the constant support, backing and encouragement received during these three years, both professionally and personally.

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This work is not only the fruit of an individual effort, but also the result of the support, inspiration and trust received from these wonderful people, to whom I will remain eternally grateful.

Doctoral thesis contents

Doctoral thesis topic and its field

This PhD thesis explores modern tools used in analyzing the relationship between capital market sentiment and investor behavior, integrating concepts from efficient markets theory, fractal theory and behavioral finance. The main field of research is finance, with relevant subfields in financial econometrics, behavioral finance and capital markets analysis. The study aims to provide a deeper understanding of how behavioral factors and nonlinear market structures can influence the volatility and price formation of financial asset prices. A central focus of the research is to identify the limitations of traditional econometric models used in the analysis of financial markets and to propose alternative approaches that better capture the realities of emerging markets. Particular emphasis is put on the Romanian stock market and the BET index, aiming to assess to what extent conventional models can be improved by integrating modern theories on chaos, fractals and market sentiment. This approach is motivated by the need for more flexible methods capable of capturing the nonlinear and behavioral characteristics of emerging markets, where traditional efficiency mechanisms do not work as well as in developed markets. The 2008 financial crisis was a turning point in understanding the shortcomings of econometric models applied to financial markets. My direct experience during that period led to a critical reflection on how financial markets are analyzed and predicted. Although the traditional econometric models and analysts' reports indicated a stable economy, the volatility of the markets was sudden and devastating, highlighting the need for new methods of analysis that take into account the complexity, non-linearity and the influence of behavioral factors on financial markets. In this context, the importance of this research lies in its contribution to our understanding of how market sentiment influences financial asset prices, as well as in highlighting the limitations of existing theories when applied to emerging markets. With almost 30 years of experience in the Romanian capital market, we considered such an analysis essential in a context where the development of the local financial market requires more accurate valuation methods adapted to current realities. This research aims not only to theoretically validate these concepts, but also to highlight the aspects that require methodological adjustments in order to improve the modeling of financial markets. Thus, the paper provides a solid foundation for future research, supporting the development of more effective methodologies to analyze market sentiment and its impact on stock market volatility. Through this research, this paper proposes a re-evaluation of the way we analyze financial markets, starting from the premises of chaos theory, fractals and behavioral finance, with the aim of developing more flexible analytical tools that are better adapted to current economic realities. This interdisciplinary approach allows a deeper understanding of market dynamics and provides an alternative to classical models based on the random walk assumption and the normal distribution of returns. The results not only provide an innovative perspective on the measurement of market sentiment, but also contribute to improving investment strategies, regulatory processes and risk assessment methodologies in emerging markets.

Research objectives

This paper was conceived with the main objective of analyzing modern methods for measuring market sentiment used by the major economic and financial theories, such as efficient market theory (EMH), fractal market theory (FMH) and behavioral finance (BF). With almost 30 years of experience in the Romanian stock market, I wanted to bring these methods to the forefront and analyze to what extent they are reflected in the reality of the local market, especially through the measurements applied to the BET index, whose evolution we have followed daily since its inception. The study aimed not only to test the applicability of these theories, but also to identify the limits of each of them, taking into account the specific characteristics of emerging markets such as Romania. In this context, the analysis was carried out using econometric methods and advanced quantitative models, with a focus on the nonlinear and fractal aspects of the market. Another important direction was the assessment of investor behavior and the impact of psychological factors on market sentiment, using established sentiment indicators and alternative methods of analysis. The main goal of the research is to analyze the methods of measuring market sentiment used in the major financial theories, such as efficient market theory (EMH), fractal market theory (FMH) and behavioral finance (BF), and to assess their applicability to the Romanian stock market, through the analysis of the BET index. The specific objectives of this research aim at a detailed analysis of the relationship between market sentiment, financial market efficiency and volatility, with a particular focus on the Romanian stock market. The study proposes to explore, from an interdisciplinary perspective, the interplay between behavioral factors, traditional econometric models and advanced nonlinear analysis methods, in order to provide a deeper understanding of emerging markets.

In this context, one of the central objectives is the theoretical exploration of the main concepts related to market sentiment and its impact on financial dynamics. This entails a critical review of the literature, analyzing how investors' collective emotions influence market volatility and financial asset pricing.

Another key objective is to assess the effectiveness and limitations of each theory in relation to the particularities of emerging markets, taking into account the specificities of the Romanian capital market. In this sense, the research examines the extent to which the efficient market hypothesis is applicable in a context characterized by low liquidity, information asymmetries and strong behavioral influences. A central aspect of the study is the application of advanced econometric methods to test whether measures of market sentiment correlate with BET market movements. Using techniques such as the Granger causality test, VAR models and volatility analysis, the research aims to determine whether sentiment indicators can serve as reliable predictors for the evolution of the Romanian stock market.

Another important objective is to analyze the chaotic behavior of the BET market by applying fractal methods, in order to assess the existence of a predictable pattern in the market dynamics. The application of the Lyapunov exponent, the Hurst exponent and the recurrence methods allows the investigation of market structures and the identification of nonlinear patterns that could influence investment strategies and risk assessment.

The research also proposes to investigate how artificial intelligence and trading algorithms influence market sentiment and stock index volatility. By analyzing the impact of automation and machine learning models on market behavior, the study offers insights into how new technologies can amplify or mitigate behavioral effects and extreme volatility.

Another fundamental objective is to assess the impact of future Romanian derivatives markets on investor sentiment and market stability. The study examines how the introduction of futures and options contracts can influence the liquidity and volatility of the local stock market, providing recommendations for regulators and market participants.

Finally, the research aims to identify differences between emerging and developed markets in terms of the validity of econometric models and their sensitivity to behavioral and structural factors. By analyzing the experiences developed, market studies provide a comparative perspective that can contribute to the development of risk management strategies and investment decision-making in emerging markets.

By achieving these objectives, the research makes a significant contribution to the understanding of the mechanisms governing financial markets, highlighting the importance of integrating classical models with innovative approaches to better anticipate volatility and investor sentiment.

This research aims to provide a more detailed understanding of the relationship between market sentiment and price fluctuations in financial assets, demonstrating how traditional analytical models need to be adjusted to better reflect the reality of emerging markets. The paper also contributes by applying an integrated methodology that combines quantitative methods and advanced econometric models, along with elements from chaos theory and fractals, to provide a more realistic perspective on the dynamics of financial markets.

Thesis Structure

This thesis is organized into four main chapters, each of which plays an essential role in developing the arguments and fundamental conclusions of the research.

The first chapter of the paper provides a detailed analysis of the theory of market efficiency, presenting its foundations and historical development, from the random walk model formulated by Louis Bachelier (Bachelier, 1900) to the classification of efficiency into weak, semi-strong and strong forms (Fama, 1970). The chapter also explores the econometric tests used to validate the efficient market hypothesis, such as random walk tests, stationarity tests. The particularities of emerging markets are also analyzed, with a special

focus on the Romanian capital market, where empirical studies have demonstrated that market efficiency is limited by low liquidity, the low presence of institutional investors and high volatility (Victor Dragota; Elena Valentin Tilica, 2013). The study applied to the BET index analyzes market efficiency and the presence of nonlinear behaviors on the Bucharest Stock Exchange (BVB) through a series of complex econometric tests, taking an integrative and multidimensional approach. The analysis explores the efficiency of the Romanian capital market, analyzing the BET index through a rigorous and extensive methodological framework, which goes beyond previous studies. The main contribution consists in applying a diversified set of econometric tests designed to capture both linear and nonlinear dependencies, providing a more detailed perspective on market mechanisms. The adopted methodology integrates fundamental tests, such as the Augmented Dickey-Fuller (ADF) test, KPSS and PP, the RUN (Wald-Wolfowitz) test and the Ljung-Box test, to assess the stationarity and autocorrelation of returns, along with advanced tests, such as the BDS (Brock-Dechert-Scheinkman) test, the Lo test of interval rescaling analysis together with the classic Hurst-Mandelbrot test, which provide a broader perspective on the nonlinear and fractal behaviors of the market. The results obtained indicate that BET does not fully respect the efficient market hypothesis in its weak form, presenting long-term memory trends and significant autocorrelations, which suggests limited predictability of returns. We also found that the BET index returns, although closer to efficiency, continue to exhibit deviations from the random walk hypothesis, thus confirming that the Romanian market is not fully efficient. These findings are consistent with the literature on emerging markets, which highlights lower efficiency compared to developed markets, due to low liquidity, low participation of institutional investors and information asymmetries. The study provides a detailed analysis of how the Romanian capital market has evolved from frontier to emerging market status, highlighting the challenges and opportunities associated with this process. By using a variety of econometric methods, the research contributes to a deeper understanding of the dynamics of the Romanian market and provides valuable insights for investors and decision-makers, suggesting possible directions to create market efficiency and develop some investment strategies more adapted to the specific context of the Bucharest Stock Exchange.

The second chapter of the paper addresses the topic of behavioral finance, which brings a new perspective on financial markets, with a focus on the influence of psychology and emotional factors on investment decisions. Unlike classical models, which assume the rationality of investors and the efficiency of markets, behavioral finance challenges these assumptions and highlights how cognitive biases and emotions influence asset prices and market dynamics. We have brought to light the fundamental theories of the field, starting with the prospect theory formulated by Daniel Kahneman and Amos Tversky, which demonstrates that investors perceive losses more intensely than gains, which leads them to adopt subjective and often irrational decisions (Daniel Kahneman and Amos Tversky, 1979). We have also highlighted the contributions of Richard Thaler, who developed the concept of

nudge, showing how the decision-making structure can influence financial choices without restricting their freedom (Thaler, 2018). In addition, Robert Shiller's analysis of speculative bubbles and irrational exuberance explains the mechanisms by which markets become unstable and how investors are guided by collective emotions rather than fundamental data (Robert J. Shiller, 1981). In this chapter, we have detailed the main cognitive and emotional biases that affect investors' decisions, such as conservatism, the illusion of control, loss aversion, the herd effect, etc., demonstrating how these thinking errors distort risk perception and suboptimal behavior in the market. We have also analyzed the role of social and conformity errors, explaining how group pressure and social norms influence investments, amplifying both excessive growth cycles and sudden market crashes. Another essential aspect addressed is the contribution of artificial intelligence to behavioral finance. We explored how machine learning algorithms and market sentiment analysis contribute to understanding investor behavior, but also how these algorithms can introduce bias errors, amplifying market volatility through automatic and exaggerated reactions to fluctuations in collective sentiment.

The research conducted, on regime change and the dynamics of capital market volatility in Romania, analyzes the behavior of the BET index and the impact of psychological factors on stock market volatility. The study highlights how investors react to information and how behavioral biases influence regime changes in the market. By applying the econometric models Markov Switching Model (MSM) (Hamilton, 1989) and ARCH (Robert F. Engle, 1982), the research identifies periods of high and low volatility, demonstrating that the market does not always behave rationally, but is marked by emotion, herding, and sentiment-based trading. The MSM model highlighted the existence of two distinct states in the evolution of BET: a downward state, characterized by negative returns, and an upward state, characterized by positive returns. The results of the study emphasize that the volatility of the Romanian capital market is not only the result of objective economic factors, but also of investor behavior. Collective emotions, disproportionate reactions to information and social conformity tendencies play an essential role in changing market regimes. These findings are particularly relevant for investors and decision-makers, underlining the importance of integrating financial psychology into investment strategies and risk management, especially in emerging markets, where these effects can amplify instability.

In Chapter 3 of this thesis, I discussed the theory of chaos and fractals, which offers an alternative to financial markets that challenges the efficient market hypothesis and traditional linear models. This chapter explores the fundamental concepts of deterministic chaos, fractals and emergent models, revealing how they can contribute to understanding the complexity of financial market behavior. The chapter approaches the dynamics of complex systems through essential concepts such as attractors, the basin of attraction, phase transitions, critical points, bifurcation points, recurrence and fractal dimension. By analyzing these elements, the unpredictable character of financial markets and their emergent nature are highlighted. I introduced the mathematical concepts used in the study

of chaos and fractals, including Lyapunov exponents and Hausdorff dimension. I also presented methods used in the description of financial market phenomena, such as R/S analysis (Rescaled Range Analysis) and the Hurst exponent (E.Peters, 1991). We examined the applicability of the concepts of chaos and fractals in risk assessment, bubble detection, and volatility regime identification. In addition, we analyzed how recurrence and bifurcation points can help detect transitions and critical points in markets. An interesting study is the one on the application of bibliometric analysis of the literature on chaos theory, an essential analysis that reflects the impact of researchers on the development of this field and outlines a clear picture of the major directions of study. Thus, we observed that a key moment in the specialized literature is represented by the year 2005, when a significant peak in the number of citations was recorded. This explosion of interest can be correlated with the publication of fundamental works or with technological advances that facilitated the application of chaos theory in various fields. After this peak, the number of citations recorded a decline, stabilizing at a lower and relatively constant level, which suggests a maturation of the field or a reorientation of research towards other directions. A complementary perspective on the literature on chaos is offered by the analysis of conceptual connections, represented by a network approach. The word "chaos" appears as the central node of this system, around which fundamental concepts such as "nonlinear", "systems", "dynamic", "complexity" and "analysis" are grouped. This semantic distribution confirms that most studies in the field are focused on investigating nonlinear dynamical systems and their inherent complexity. Also, the presence of terms such as "financial", "stock" and "market" signals an increased interest in applying chaos theory to the analysis of financial markets, indicating that, although this subfield is still emerging, it is gaining more and more attention among researchers. These results suggest that chaos theory not only remains a relevant tool in the study of complex systems, but it also extends its applicability to the fields of economics and finance, contributing substantially to the analysis of market behavior and their fluctuations.

Chapter 4 of the paper is dedicated to the analysis of classical sentiment indicators in capital markets, a subject that plays an essential role in understanding investor behavior and market dynamics. Thus, following a review of the specialized literature and analyzing the major contributions of researchers in the field of sentiment indicators, we have provided a detailed picture of how investor sentiment influences financial markets and how it can be measured through a variety of indicators. This analysis highlights the fact that the integration of these indicators into trading strategies could, to a certain extent, improve the decision-making process, especially in times of high uncertainty, taking into account three main categories of indicators: technical, fundamental and macroeconomic. We started from the use of moving averages (SMA, WMA, EMA), also mentioning classic technical analysis indicators such as MACD, RSI, stochastic oscillator and Boolinger bands, emphasizing how they reflect the collective psychology of investors and can provide predictive signals about overbought or oversold moments. We also highlighted the role of PER and EPS in fundamental analysis, as well as the influence of interest rates and inflation on risk

perception. An important segment is dedicated to volatility indicators, with a focus on the VIX index, known as the "fear index", and the VXN, specific to the Nasdaq market. We also analyzed the Beta coefficient as a measure of risk as well as the impact of the Put-Call ratio (PCR) on investor behavior. At the end of the chapter, we conducted research that investigates the relationship between the Put-Call ratio (PCR) and financial market indices, analyzing to what extent this sentiment indicator influences stock market performance, with a special focus on the S&P 500 and BET. The study is relevant in the context of the Romanian market, where the absence of derivatives and low liquidity raise questions about the applicability of PCR as a predictor of market movements. Using a vector autoregressive model (VAR), Granger causality tests and impulse-response functions (IRF), the research evaluates the correlations between PCR and market indices over an economically stable period, between 2016 and 2019. The results indicate that PCR does not have a significant predictive capacity on BET and S&P 500, and its impact on the Romanian market is insignificant. The correlation analysis shows weak relationships between PCR and market indices, which highlights the limitations of its application in capturing investor sentiment in an emerging market like Romania. These findings suggest that PCR cannot be used as a reliable tool for analyzing local market sentiment, and for a better understanding of market dynamics, the integration of additional indicators, such as VIX or VXN, as well as the use of more sophisticated econometric models would be necessary. In view of the future establishment of a derivatives market in Romania, this study highlights the need for methodological adjustments in the analysis of investor sentiment, emphasizing that, in its current form, an indicator such as PCR is limited as a tool for predicting market trends, although its perception may be confusing for participants.

The conclusions of this research highlight the fact that traditional financial analysis models need to be re-evaluated to better reflect the complexity of markets. The integration of chaos theory, fractals and behavioral finance offers an alternative more adapted to the contemporary financial reality. As Romania prepares for the introduction of derivatives markets, it is essential that investors and decision-makers adopt a more nuanced perspective on how market sentiment influences stock market dynamics. This research contributes to the specialized literature by highlighting the need for more flexible and adaptable econometric models, capable of capturing the emergent and unpredictable nature of modern financial markets. In conclusion, the structure of the thesis is designed to provide an in-depth analysis of the main financial theories, testing their validity on the Romanian market and highlighting the need for new approaches in the analysis of investor sentiment and financial market dynamics.

Research Methodology

The methodology adopted in this thesis reflects a complex and multidimensional approach, designed to capture financial market dynamics from a holistic perspective. It integrates classical econometric models with modern methods of analyzing market complexity and sentiment, providing a robust framework for investigating the Romanian capital market and the BET index. The study uses a combination of statistical tests, regression models and advanced chaos and fraction analysis techniques, providing a thorough understanding of the relationship between market sentiment and stock market volatility. The integrative approach was necessary to overcome the limitations of traditional econometric models and to more accurately reflect the characteristics of emerging markets. Methods of Market Efficiency and Random Walk Analysis

- Methods of Market Efficiency and Random Walk Analysis

To assess whether the Romanian capital market complies with the weak form of the efficient market hypothesis, several statistical tests were used to detect the presence of autocorrelations and dependencies in the BET index return:

- Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979)– used to check the stationarity of the return series and to determine whether they follow a random process. Stationarity is essential in the application of econometric models and allows the identification of the presence of deterministic structures in the data.
- RUN (Wald-Wolfowitz) test (Wolfowitz & J., 1944) – applied to detect whether the return series follows a random walk. This non-parametric test checks whether the sequence of values of a series presents an ordered structure or is randomly distributed.
- Ljung-Box (Portmanteau Q) test (Lyung G.M. and Box G.E., 1978) – used to examine autocorrelations in the return series, providing information about short-term dependencies. This test is essential to determine whether prices are independent of each other, as assumed by the efficient market hypothesis.
- BDS (Brock-Dechert-Scheinkman) test (Brock, Dechert, Scheinkman & LeBaron, 1996) – applied to identify nonlinear structures in the data. Unlike classical tests, which detect only linear dependencies, the BDS test highlights the hidden nonlinear relationships in financial series, providing a more detailed diagnosis of the market.

- Methods for analyzing long-term memory and fractal behavior of the market

Given that financial markets can exhibit persistence and long-term memory, specific methods have been used to assess the influence of past values on future price fluctuations:

- Hurst-Mandelbrot R/S test – used to detect the presence of long-term memory. The Hurst coefficient determined by this indicates whether the market has a persistent character ($H > 0.5$), anti-persistent ($H < 0.5$) or follows a random process ($H \approx 0.5$).
- Modified Lo R/S test – an extension of the classic R/S method, which provides a more robust estimate of long-term memory persistence, eliminating the effects of excessive volatility in data series.

- Regime Switching and Volatility Models

To understand transitions between different market regimes and the impact of investor sentiment on volatility, research using advanced econometric models:

- Markov Switching Model (MSM) (Hamilton, 1989)– applied for identifying market regimes by analyzing transitions between periods of high and low volatility. This model highlights the moment when the market is in a regime of sustained growth or accelerated decline.

- ARCH (Autoregressive Conditional Heteroskedasticity) Model (Robert F. Engle, 1982) – used to measure the dependence of volatility over time and to explain how market shocks influence subsequent price fluctuations. This model is essential in analyzing the persistence of volatility and the phenomenon of "clustered volatility".

- Chaos and fractal analysis methods

To test the hypothesis that financial markets are chaotic and nonlinear systems, specific techniques of chaos theory were applied:

- Lyapunov Exponent – used to measure the sensitivity of initial conditions, indicating the degree of unpredictability of the market and confirming its chaotic character.

- Henon Map and Lorenz Attractor – used to visualize market dynamics and determine whether it has a fractal structure. These tools help identify market regimes and nonlinear relationships in price evolution.

- Logistic Map – applied to observe cyclical behaviors and periods of predictability of the financial market.

- Models of interdependence between market sentiment and stock indices

A central aspect of the research was the analysis of the relationship between market sentiment, measured by the Put-Call ratio (PCR), and the evolution of the BET and S&P 500 stock indices.

- The VAR (Vector Autoregressive Model) model – used to capture the dynamic interactions between PCR, S&P 500 and BET. This model allows the identification of direct and indirect effects between interdependent economic variables.

- The Granger test (Granger, 1981) – applied to determine the direction of causality between variables, establishing whether PCR influences the evolution of stock indices or if the relationship is inverse.

- The Impulse Response Function (IRF) – used to analyze the impact and propagation of shocks in the financial system. This tool allows the assessment of how a shock to one variable affects the other variables over time.

I will synthesize these models used in the paper, as follows:

Types of research, applied methodologies, objectives

No.	Research Type	Methodology	Objectives	Chapter	Data Used
1	Quantitative	ADF Test	To verify the	1	BET data

			stationarity of return series and determine whether they follow a random process. Stationarity is essential for applying many econometric models and allows identifying deterministic structures in data.		from 17.01.2000-19.01.2024
2	Quantitative	RUN Test	To detect whether the BET returns series follows a random walk. This non-parametric test checks whether the sequence of values has a random distribution or a structured pattern.	1	BET data from 17.01.2000-19.01.2024
3	Quantitative	Lyung Box Test (Portmanteau Q)	To examine autocorrelations in the return series, providing information on short-term dependencies. This test is crucial for establishing if prices are	1	BET data from 17.01.2000-19.01.2024

			independent, as assumed by market efficiency theory.		
4	Quantitative	BDS Test	To identify nonlinear structures in data. Unlike classical tests that detect only linear dependencies, BDS test reveals hidden nonlinear relationships in financial series.	1	BET data from 17.01.2000-19.01.2024
5	Quantitative	Lo's Modified R/S Test	To examine long-term dependencies with more robust confidence than the classic Hurst Mandelbrot test, providing a robust estimate of long-term memory persistence by removing excessive volatility effects from the series.	1	BET data from 17.01.2000-19.01.2024
6	Quantitative	R/S Hurst-Mandelbrot Test	Classical method for identifying long-term memory presence. The Hurst coefficient indicates if the market has a	1	BET data from 17.01.2000-19.01.2024

			persistent character.		
7	Quantitative	Markov Switching Model (MSM)	To identify market regimes by analyzing transitions between periods of high and low volatility. This model highlights periods of sustained growth or accelerated decline.	2	BET data from 17.01.2000-19.01.2024
8	Quantitative	ARCH Model (Autoregressive Conditional Heteroskedasticity)	To detect volatility clustering in BET returns series. This econometric model measures volatility dependence over time, explaining how market shocks influence subsequent price fluctuations.	2	BET data from 17.01.2000-19.01.2024
9	Quantitative	Bibliometric analysis of chaos-related concepts	To analyze interest in chaos theory both generally and specifically in finance.	3	Keywords such as 'chaos', 'nonlinear', 'systems', 'dynamic', 'complexity', 'analysis', 'financial', 'stock', 'market'
10	Quantitative	R/S Analysis	To identify long-	3	BET data

		(Rescaled Range) for Hurst exponent calculation	term memory presence in BET data series.		from 17.01.2000-19.01.2024
11	Quantitative	Hurst Exponent	To identify persistence/anti-persistence zones in BET data series.	3	BET data from 17.01.2000-19.01.2024
12	Quantitative	Lyapunov Exponent	To determine sensitivity to initial conditions, measuring how quickly two nearby trajectories diverge. It is fundamental for detecting chaos in returns series.	3	BET data from 17.01.2000-19.01.2024
13	Quantitative	Henon Map	To visualize data structure, market regimes, and relationships between successive BET values.	3	BET data from 17.01.2000-19.01.2024
14	Quantitative	Logistic Map	To visualize periods of predictability in BET index.	3	BET data from 17.01.2000-19.01.2024
15	Quantitative	Lorenz Attractor	To visualize BET index movements, stability periods, and attempts to return to equilibrium.	3	BET data from 17.01.2000-19.01.2024
16	Quantitative	VAR Model (Vector Autoregressive Model)	To capture dynamic interactions	4	BET data from 06.07.2016-

			between PCR, S&P 500, and BET. This model identifies direct and indirect effects among interdependent economic variables.		04.10.2019
17	Quantitative	Granger Causality Test	To determine the direction of causality between variables, establishing if PCR influences stock index evolution or vice versa.	4	BET data from 06.07.2016-04.10.2019
18	Quantitative	Impulse Response Function (IRF)	To study the impact and propagation of shocks of one variable on the others (PCR, S&P500, and BET).	4	BET data from 06.07.2016-04.10.2019

The methodology adopted in this research provides a robust and innovative framework for the analysis of emerging financial markets, combining traditional econometric models with advanced techniques from chaos theory and fractals. This approach allows for a better understanding of market dynamics, investor sentiment, and the nonlinear processes that influence volatility and price formation. By integrating these methods, the research contributes to the development of more flexible analytical tools, capable of capturing the real complexity of financial markets and providing alternatives to classical models based on the random walk hypothesis.

Advantages and limitations of the method used

The methodology adopted in this research offers a complex and innovative perspective on financial markets, combining traditional statistical approaches with advanced nonlinear analysis models. This methodological integration allows for a more detailed understanding of market dynamics, but at the same time also implies certain inherent limitations.

Advantages of the methodology

- A first major advantage is the multidimensional approach, which combines classical statistical methods with advanced chaos and fractal analysis techniques. In this way, the research is not limited to traditional linear econometric models, but captures the complexity of financial markets in a more realistic way. This allows the identification of mechanisms that cannot be detected by classical analysis, providing a more accurate picture of the behavior of emerging markets.
- A second significant advantage consists in the detection of nonlinear relationships, achieved by using the BDS, Hurst and Lyapunov tests. These methods are essential for highlighting subtle and recurring patterns that cannot be captured by ordinary econometric regressions. For example, the Hurst test allows determining the degree of long-term memory of the market, while Lyapunov exponents identify the existence of deterministic chaos in price movements. Thus, the research contributes to overcoming the limitations of the efficient market hypothesis, demonstrating that financial markets can exhibit predictable dynamics under certain conditions.
- Another advantage of the methodology is the dynamic analysis of volatility, carried out through the MSM (Markov Switching Model) and ARCH models. These models allow highlighting regime changes in volatility and identifying moments when the market goes through phases of heightened instability. The integration of these models makes an important contribution to understanding the impact of market sentiment on price fluctuations and recognizing sudden transitions between different volatility regimes.
- Last but not least, the methodology used adds a behavioral component, by testing the relationship between the Put-Call Ratio (PCR) and stock market indices. This approach allows for a more detailed investigation of the emotional influence of investors on financial markets. The results obtained show that market sentiment not only reflects price movements, but can contribute to their amplification, thus highlighting the importance of integrating psychological factors into financial market analysis models.

Methodological limitations

Although the proposed methodology brings multiple advantages, it also has certain limitations.

- the first limitation is the dependence on data quality. Nonlinear models and fractal tests are sensitive to the data series and can be influenced by the presence of statistical noise. Thus, any discontinuity or error in the data can affect the accuracy of the estimates.

- Another aspect that should be mentioned is the complexity of interpreting the results. Unlike classical econometric models, models based on chaos theory and fractals require a more in-depth analysis in order to be integrated into applicable investment strategies. For example, although the Lyapunov exponents indicate the presence of a chaotic system, the interpretation of these values in terms of price predictability remains an open subject.
- another limitation of the methodology is the generalizability of the results. Although the analysis provides relevant conclusions for the Romanian capital market, the applicability of these findings in other emerging markets may be limited by factors such as low liquidity, institutional interventions or the degree of integration into international markets.
- In addition, the models used do not take into account the impact of major exogenous events (financial crises, political changes, new regulations), which can influence market sentiment and stock index volatility in an unpredictable way. Although the fractal approach allows the detection of patterns in historical data, it cannot anticipate sudden shocks that abruptly change the market structure. This innovative methodology allows for a deeper understanding of how financial markets work, overcoming the limitations of traditional econometric models and providing a more realistic perspective on the complexity of the capital market.

In conclusion, the methodology used in this research offers an innovative perspective on the financial market, integrating traditional models with advanced nonlinear and behavioral analysis techniques. It allows the detection of complex relationships between investor sentiment, volatility and market movements, highlighting the importance of a multidisciplinary approach. However, limitations related to data quality, interpretation of results and applicability of conclusions to other emerging markets should be considered for future research.

Original results, conclusions, contributions to the scientific field and relevance

This doctoral thesis makes a significant contribution to the complex understanding of financial markets, offering an innovative perspective on the interactions between market sentiment, investor behavior and stock index dynamics. By integrating classical theories with advanced methods of chaos analysis, fractals and behavioral finance, the study highlights the limitations of traditional econometric models and proposes new approaches for interpreting emerging markets. A major contribution of this research consists in applying a multidisciplinary methodology to the analysis of the Romanian capital market, a relatively little explored field from the perspective of chaos and fractals. The study demonstrates that market volatility cannot be explained only by traditional linear models, but requires an approach that takes into account the fractal structure of the market and the existence of chaotic behavior. In this sense, the results obtained by using the Lyapunov and Hurst exponents confirm the presence of significant nonlinear features in the dynamics of financial

asset prices. Another important contribution of the thesis is the investigation of the relationship between market sentiment, measured by the Put-Call Ratio (PCR), and stock market index volatility. The results obtained show that, in the case of the Bucharest Stock Exchange (BVB), investor sentiment does not directly anticipate market movements, but is rather a reactive factor to price changes. This perspective is essential for investors and analysts, as it highlights the importance of combining sentiment indicators with other economic and financial variables for a more accurate market assessment. In addition, the research highlights the implications that the future Romanian derivatives market may have on investor sentiment and market stability. The introduction of these financial instruments could lead to increased liquidity and the development of more sophisticated hedging strategies, but, at the same time, could amplify market volatility in the absence of adequate regulatory mechanisms. These conclusions are particularly relevant for supervisory authorities and market participants, as they can provide a framework for anticipating the impact of these changes on market structures. This research has demonstrated that integrating multiple perspectives – econometrics, behavioral finance and fractals – can provide a deeper analysis of financial market dynamics. This complex approach not only broadens the understanding of emerging market behavior, but also contributes to the development of more robust methods for measuring market sentiment and financial volatility. Thus, the research provides both a theoretical contribution by developing an extended conceptual framework, and an applicative contribution by empirically testing innovative models on the Romanian capital market.

Original research results

Following the application of econometric tests and advanced models, this research generated a series of original results that contribute to a deeper understanding of emerging markets and the factors that influence their efficiency. These findings bring new perspectives on the dynamics of the Romanian capital market, providing solid arguments for the reevaluation of classical theories regarding market efficiency and the influence of investor sentiment. A first significant result of the study concerns the confirmation of the deviation of the Romanian capital market from the weak-form efficiency hypothesis. The analysis performed on the BET index demonstrated that the Romanian market does not fully follow the random walk hypothesis, as the ADF, KPSS, PP, RUN and Ljung-Box tests indicated the presence of autocorrelations and predictable structures in returns. This finding suggests that investors can use historical information to anticipate future price movements, which contradicts the weak-form market efficiency paradigm.

Another important result is the identification of long-term dependence and the fractal nature of the market. The application of the Hurst-Mandelbrot R/S and Lo R/S tests highlighted the presence of long-term memory in the return series, indicating a persistence of market

trends. The obtained Hurst coefficient confirms that the market presents long-term memory characteristics, contradicting the hypothesis according to which returns are randomly distributed. This result supports the idea that financial markets function as complex adaptive systems, governed by emergent and nonlinear properties. An essential contribution of the research is the highlighting of regime changes in market dynamics, achieved by applying the Markov Switching Model (MSM). The obtained results show that the Romanian market oscillates between distinct regimes of high and low volatility. The high probability that the market remains in a stable regime after a growth phase indicates the existence of a herd effect, where investors tend to maintain current trends in the long term. This conclusion is relevant for investment strategies, suggesting that trend changes are not sudden, but evolve progressively, influencing investor sentiment and expectations.

Another fundamental aspect investigated is the impact of investor sentiment on market volatility, highlighted by the ARCH model. The results indicate that periods of high volatility are followed by similar periods, confirming an auto-correlated behavior of volatility. This finding emphasizes that emotional factors and investors' perception of risk play a crucial role in shaping market evolution, with direct implications for risk management and asset allocation strategies. An innovative contribution of the thesis is the validation of chaos theory in the analysis of financial markets, by applying the Lyapunov and Hurst exponents. The results confirm that the Romanian stock market presents chaotic characteristics, which indicates a high degree of unpredictability. The results emphasize the need to adopt alternative analysis methods, which allow the identification of these periods of stability and chaos, thus contributing to a new perspective on the dynamics of emerging markets. In addition, the research analyzed the interdependence between the Put-Call Ratio (PCR) and stock indices, highlighting that PCR is not a strong predictor of market movements. The Granger causality test and the VAR model showed that although PCR reflects investor sentiment, its influence on stock indices is limited. This finding is particularly important for sentiment-based investment strategies, suggesting that using PCR alone as an indicator of market direction is insufficient and that we need to consider other factors, such as macroeconomic indicators and other structural factors. With these results, the research makes a significant contribution to the emerging markets literature, demonstrating that they are characterized by structural anomalies, nonlinear patterns and behavioral influences that cannot be fully explained by traditional models of market efficiency. The integration of fractal, chaotic and behavioral analyses into an applicable econometric framework for Romanian capital offers a new approach to measuring market sentiment and predicting volatility, thus contributing to the development of more flexible and adaptive models for analyzing emerging financial markets.

Research Conclusions

This research aimed to investigate the limits of traditional econometric models in the anticipation of financial crises, analyzing the role of market sentiment, behavioral finance theories, and concepts from chaos theory and fractals in explaining financial market dynamics. Starting from the fundamental question regarding the inability of the global financial system to anticipate the 2008 crisis, the paper explored the criticisms brought to the efficient market hypothesis, offering an alternative based on more complex models, capable of capturing the emergent behavior of markets. The results obtained indicate that models based exclusively on equilibrium and their normal distributions are not sufficient to analyze market volatility, and the integration of alternative perspectives is necessary for a better prediction of system risks. In the empirical analysis of the Romanian capital market, the research demonstrated that the BET index does not fully comply with the efficient market hypothesis, presenting autocorrelations in data and long-term memory, which suggests limited predictability of returns. The econometric tests applied indicated the presence of nonlinear characteristics in market behavior, and the use of Markov Switching and ARCH models highlighted the existence of regime changes determined not only by economic factors, but also by investors' perceptions and emotional reactions. These findings are consistent with studies conducted on emerging markets, which emphasize the strong impact of behavioral factors on stock market dynamics. Another important aspect analyzed in the research was the relationship between investor sentiment, measured by the Put-Call ratio (PCR), and stock market indices. The results indicated that PCR is not a reliable predictor of market movements in Romania, and its influence on the BET index is insignificant. These results confirm the hypothesis that the effectiveness of sentiment indicators is determined by market maturity and the availability of financial derivatives. In emerging markets, where such instruments are either non-existent or poorly developed, the ability of sentiment indicators to anticipate market movements is much reduced.

These findings have important implications for both investors and policymakers. In the context of the future implementation of the derivatives market in Romania, it is essential to understand the limitations of traditional models and to develop more flexible methodologies that capture the nonlinear characteristics of the market. In particular, the adoption of models based on chaos theory and fractals, the integration of volatility indicators such as the VIX and the application of network analysis could contribute to increasing financial forecasts and reducing the risks associated with market instability. In the field of chaos theory, recent research confirms that chaotic models can better describe the structural price patterns of financial assets. The combined analysis of the Hurst exponent, the Lyapunov exponent, the Lorenz attractor, as well as the logistic map and the Henon map provides an in-depth insight into the dynamics of the BET index. The results indicate a complex system, located on the border between chaos and order, in which the sensitivity of initial conditions is present, but does not predominate. The market shows a long-term memory and a significant persistence

of trends, which limits the applicability of traditional models, but does not completely exclude them. The correlated analysis of these indicators confirms that BET is a complex system, characterized by a combination of structural stability and episodes of local instability, which makes the evolution partially predictable, but vulnerable to exogenous disturbances.

These conclusions suggest that strategies based on the recognition of volatility regimes and fractal analysis can be more effective than standard models of efficient market theory, offering a more nuanced approach to market mechanisms and price dynamics. However, the applicability of these models is limited by the mathematical complexity and the difficulty of interpreting the results. Also, recent bibliometric analyses show that although interest in fractal models has increased, their use in economics is still restricted to specialized research.

The conclusions of this research confirm the need for an interdisciplinary approach in the analysis of financial markets, emphasizing that traditional models must be complemented by innovative methods to capture the real complexity of markets. The integration of chaos theory, fractal models and behavioral finance in the analysis of the Romanian capital market highlights a series of essential aspects for understanding the dynamics of emerging markets and the factors that influence their efficiency. A first fundamental result of the research is the demonstration that the efficiency of financial markets is not an absolute concept, but a dynamic one. The econometric and fractal results obtained show that market efficiency is influenced by a combination of structural, behavioral and economic factors. The Romanian capital market, similar to other emerging markets, presented anomalies and specific characteristics, being marked by low liquidity and information asymmetries. These aspects reduce market efficiency, allowing investors to exploit certain predictable patterns, contradicting the weak-form efficiency hypothesis. Another crucial aspect confirmed by the research is that financial markets cannot be explained by linear models alone, requiring an approach based on chaos theory and fractals. Classical market efficiency models and traditional statistical analysis fail to capture the real complexity of market movements. By applying Lyapunov exponents, the Hurst test and chaotic attractor analysis, it has been demonstrated that markets exhibit nonlinear behaviors, long-term memory and fractal patterns. These results highlight the fact that financial asset prices do not always evolve randomly, but follow recurring patterns that can be identified and analyzed by alternative methods. The research also confirms that investor sentiment has a strong impact on market volatility. Behavioral and emotional factors influence market mechanisms, determining regime changes and affecting the persistence of volatility. The application of the ARCH and MSM models showed that market volatility is not randomly distributed, but tends to be auto-correlated, reflecting phases of panic and euphoria. These results emphasize the integration of psychological factors in investment strategies and risk management models, investors' decisions are not strictly rational, but are influenced by the collective perception of the market. In addition, the empirical analysis demonstrated that classical sentiment indicators have limitations in emerging markets. The results of the Granger causality tests

and the VAR model indicate that the Put-Call ratio (PCR) cannot be used as a robust predictor of market movements in Romania. These results suggest that emerging markets require more advanced sentiment measurement tools that can effectively capture the collective emotions of investors. Alternative integration, which combines classical analysis, macroeconomic factors and volatility indicators, could be capable of predicting market sentiment and provide a deeper understanding of how investor perceptions influence price formation.

In conclusion, this research highlights the importance of a multidisciplinary perspective in the analysis of financial markets, demonstrating that traditional approaches must be complemented by fractal models, chaos theories and behavioral finance to explain the complexity of observed phenomena. The results obtained provide a useful conceptual and application framework for both investors and analysts, as well as regulators, contributing to the development of more robust methods for assessing market sentiment and financial volatility in the context of emerging markets.

Contributions to the scientific field

This work makes significant contributions to the fields of finance, econometrics and behavioral finance, providing an innovative perspective on the dynamics of financial markets and on the factors that influence their volatility and efficiency. The research proposes a multidimensional approach, integrating advanced methods of fractal and chaotic analysis with traditional econometric models and behavioral finance theories, thus providing a more complex and adaptable framework for the development of emerging markets.

A major contribution of this work consists in the integration of methods from chaos theory and fractals in the analysis of financial markets. The use of recurrence analysis, Lyapunov and Hurst exponents adds a new dimension to the assessment of stock market behavior, demonstrating that financial asset prices are not randomly distributed, but follow a recurrent and nonlinear structure. This approach offers an alternative to traditional linear models, allowing the identification of phases of extreme stability and instability in financial markets.

The paper also contributes to the development of an alternative perspective on market efficiency, demonstrating that this concept cannot be viewed as a fixed and universally valid one. The results obtained suggest that market efficiency is a dynamic phenomenon, influenced by economic, behavioral and structural factors, and emerging markets present particularities that cannot be fully explained by the traditional efficient market hypothesis.

This finding has important implications for investors and regulators, highlighting the need for a more flexible and adaptive approach in the analysis of financial markets. Another fundamental aspect validated by this research is the essential role of behavioral factors in determining market volatility. The study confirms that market fluctuations are strongly influenced by the emotions and collective feelings of investors, and these elements cannot

be neglected in modeling price evolution. By applying econometric tests and ARCH and MSM models, the research shows that extreme volatilities are not only the results of fundamental market mechanisms, but are amplified by psychological factors and investors' reactions to uncertainty and exogenous events. This conclusion highlights the need to adjust classical econometric models to integrate sentiment variables and behavioral factors in the analysis of risk and volatility in financial markets. In conclusion, this paper provides a substantial contribution to the field of finance by proposing a complex and innovative methodological framework that combines traditional econometric models with advanced techniques from chaos theory and fractals, while highlighting the importance of investor sentiment in emerging market dynamics. The results obtained not only add new theoretical insights into market efficiency and financial volatility, but also provide relevant practical applications for investors, analysts and regulators, thus contributing to the creation of analysis and decision-making strategies in the investment environment.

Research Relevance

The results of this research are particularly relevant for investors and financial market decision-makers, providing a deeper understanding of emerging market dynamics and the interactions between market efficiency, volatility and investor sentiment.

- For investors, the study provides essential tools for identifying investment opportunities by analyzing the fractal behavior of the market and integrating sentiment indicators. The use of advanced analysis techniques, such as Lyapunov and Hurst exponents, as well as ARCH models, allow for better anticipation of volatility regimes and transitions between stability and chaos. These findings contribute to the development of more robust investment strategies that take into account the complex mechanisms governing emerging financial markets;
- For regulators, the research highlights the need to develop more transparent and efficient financial markets, capable of reducing the impact of information asymmetries and speculative phenomena. The results show that emerging market volatility is not solely driven by fundamental economic factors, but also by collective investor behavior, which requires more sophisticated regulatory measures. Implementing mechanisms to more closely monitor market sentiment and reduce speculative extremes could contribute to better financial stability and greater market predictability;
- For researchers, this paper provides an innovative methodological framework that can be extended to other emerging markets to analyze the relationships between market efficiency, volatility, and investor behavior. Integrating chaos theory and fractals into financial analysis opens new perspectives on how markets evolve over time and how recurring patterns in price movements can be identified. In addition, the use of advanced techniques to test

volatility regimes and market sentiment provides a model that can be applied in future studies of financial markets in other regions.

This contribution opens new research directions and consolidates a more realistic approach to financial markets, adapted to the current economic complexity. The results obtained highlight the need for an interdisciplinary perspective that combines econometrics, behavioral finance and complex systems theory, thus providing a more appropriate analysis model for understanding emerging markets and for optimizing investment and regulatory decisions. Through this contribution, the thesis opens new research directions, consolidating a more realistic approach to financial markets in the context of the current economic complexity. A fundamental aspect that could be reconsidered in modern economics is the way we describe and interpret economic laws. Traditionally, econometric models have been based on the classical conception of time as a constant and universal variable. However, new discoveries in physics, especially in the field of complex systems and irreversible thermodynamics, suggest that this approach may be inadequate for describing real economic processes. Physicists have demonstrated that time is not a universal constant, but rather an emergent phenomenon, dependent on the dynamics of the observed system. In this sense, econometric models should adapt to capture not only traditional causal relationships, but also the evolution of economic systems in terms of emergent states and phase transitions. This idea is consistent with chaos theory and fractal models, which suggest that financial markets do not follow a predictable linear behavior, but are governed by a dynamic structure, are sensitive to initial conditions, and are characterized by self-similarity.

Ilya Prigogine, a Nobel laureate for his contributions to irreversible thermodynamics, has shown that complex systems far from equilibrium evolve through a process of self-organization driven by fluctuations and instabilities. This perspective is highly relevant to financial markets, which behave as nonlinear systems, where small changes can have disproportionate effects on the overall dynamics. Prigogine argued that in open systems, order can emerge spontaneously from chaos, which contradicts the traditional view of markets as perfectly efficient or completely random (Prigogine, 1980). One of Prigogine's key concepts is the irreversibility of time, according to which complex systems do not evolve deterministically, but through a process of successive bifurcations that create new emergent structures and behaviors. Applying these ideas to economics could involve developing models that do not assume a fixed time frame, but one that captures successive market states and how they interact with external factors. This would allow a better understanding of economic phenomena such as financial crises, regime changes and periods of structural transition. Thus, the future of econometric research should move towards the integration of methodologies inspired by physics, in particular chaos theory and complex systems theory. Models should be designed in a pragmatic and realistic way so as to capture the internal dynamics of economic systems, without imposing the assumption of linear and constant time. In this way, more faithful representations of economic reality could be obtained, which

take into account instabilities, sudden changes and the emergent nature of financial market structures. This paradigm shift could have profound implications for the way we interpret market efficiency, investor behaviour and the impact of exogenous factors on the global financial system. Therefore, the approach in Prigogine's work could represent a promising direction for future research in the field of nonlinear economics and financial market modelling.

The application of artificial intelligence in modeling financial complexity is also a current direction that brings extraordinary opportunities in this regard. Thus, the development of deep learning algorithms capable of recognizing nonlinear patterns and anticipating sudden market transitions can significantly improve economic forecasting models, as well as the integration of AI with fractal analysis and chaos theory, to build hybrid models that can identify points of instability in markets, can also provide more robust predictions. In this sense, one of the future research directions should also include and develop some hybrid models, combining fractal analysis and machine learning methods to capture emerging patterns of financial markets. In conclusion, this paper emphasizes the need for a paradigm shift in the analysis of financial markets. In order to understand markets as they are, and not as we want them to be, it is essential to abandon simplifying assumptions and accept the fact that financial markets are complex and nonlinear systems influenced by behavioral factors. Their integration can better reflect global reality and contribute to the development of investment strategies more adapted to the current conditions of financial markets. Modern economics should move away from traditional models based on the assumption of constant time and predictable market evolution. Future research should aim at developing nonlinear, adaptive and emergent models that better capture the complexity of economic reality. An integration of these ideas in econometrics could revolutionize the understanding of financial processes, allowing for better anticipation of crises and a more realistic modeling of market behavior. The conclusions of this research directly reflect the proposed objectives, synthesize both theoretical and empirical contributions.

List of scientific papers developed/published in the field

PhD ȚABĂRĂ GENIA-IULIA

Published works

1. International Journal of Science, Engineering and Technology
Tabara,G (2024): Market Efficiency and Nonlinearity: An Empirical Examination of the BET Index on the Bucharest Stock Exchange
ISSN(O): 2348-4098 – ISSN(P): 2395-4752
DOI: /10.61463/ijset.vol.12.issue5.251; Volume 12 Issue 5
Available to : https://www.ijset.in/volume-12-issue-5/

2. Bulletin of the Transilvania University of Brasov. Series V: Economic Sciences
Tabara, G (2024): Regime shifts and volatility dynamics in the Bucharest Stock Market: a Markov Swirching and ARCH Perspective
DOI: https://doi.org/10.31926/but.es.2024.17.66.2.8
Published: 2024-12-20; Issue Vol. 17(66) No. 2 (2024); Section; FINANCE AND ACCOUNTANCY
Copyright (c) 2024 Bulletin of the Transilvania University of Brasov. Series V: Economic Sciences
Available to: https://webbut.unitbv.ro/index.php/Series_V/article/view/8683

3. Journal of Smart Economic Growth
Tabara,G (2025): Exploring the Relationship Between the Put Call Ratio and Market Indices : A Comparative Analysis of S&P 500 and BET "
Published :2025-03-12 Issue Vol 9 No 3 (2024): 9-3-2024
Available to: https://jseg.ro/index.php/jseg/article/view/287

List of conference participations

PhD ȚABĂRĂ GENIA-IULIA

1. The 8th International Conference "Recent Advances in Economic and Social Research" (RAESR 2022), *Bucharest, Romania 13-14 December 2022. G.Tabara,* „Weaknesses of the Efficient Market Hypothesis (EMH) addressed by new interdisciplinary theories" https://raesr.ipe.ro/files/RAESR_program2022.pdf

2. The Sixth Edition of the International Conference

"Inclusive and Sustainable Economic Growth. Challenges, Measures and Solutions" (ISEG 2023), Brasov, 26th May 2023. G.Tabara, "Inefficiencies of Efficient Market Hypothesis"
https://bbb.unitbv.ro

3. XXV Conference on International Economics XII Meeting on International Economics, Spania, Alicante 13-14 iunie 2024. G. Tabara, Session III- International Finance „Analyzing Returns of S&P 500 Subseries derived from Rescaled Range Analysis"

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